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PROVIDING A RAPIDLY DEVELOPING COUNTRY WITH ELECTRIC POWER

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Providing a rapidly developing country with electric power

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Industrial development means that less and less muscle power is required to do more and more work. Nature has provided mankind with lavish sources of energy that may be brought to serve for the purpose but usually it is not expedient to use them directly. Electricity has served as the best medium so far and the state of a country's industrial development can more or less be gauged by the amount of electricity available per capita. Table 1 gives some examples in that respect.

Norway	7003	Australia	1750
Canada	5400	Finland	1581
USA	4111	Austria	1509
Sweden	3669	Checkoslovakia	1372
Switzerland	2719	Belgium	1359
New Zealand	2263	France	1299
United Kingdom	2005	Netherlands	1166
East Germany	1900	USSR	1100
West Germany	1765		

Table 1. Electric power consumption per capita and year (1959) measured in kWh.

Electricity may be produced by thermal power with steam or gas turbines from coal, oil, natural steam or gas or for that matter in smaller quantities by diesels. Wind power and water power may be used whenever available and the latest source of energy is nuclear. So far generators are driven by the mechanical prime mover and alternating current is used for the transmission to the point of usage.

Electricity provides lighting, drives motors, heats steel furnaces, stirs the melt, turns papermaking machines and printing presses, moves rolling mills and deep shaft winches. It allows one man single handed to carry out the work that it in his forefathers time took hundreds and hundreds of men to achieve in a less technically developed period of civilization.

Interesting is of course the question of how fast such development may take place and all countries compete in that respect trying to replace human power by means of machinery thereby getting nearer and nearer what they consider to be a welfare state. Amazingly enough there however appears to be a natural limit to such development and generally the use of electricity is not more than doubled in any one country inside a decade. Table 2 shows an interesting example from Sweden and Table 3 lists the actual development up to 1961 inside the two European units EEC (the common market) and EFTA (the free trade area) together with anticipated increase up to year 1966.

1910	1	TWh = 1.000.000.000 kWh
1920	2	
1930	4	
1940	8	
1950	16	
1960	32	

Table 2. Electrical consumption in Sweden. Increase by doubling each decade.

	EEC		EFTA		7.2 % yearly rate
1959	274.235		480.507		
1960	304.591	11 %	533.801	11 %	7.2
1961	327.430	19.5 %	574.371	19.5 %	14.9
1962	352.070	28.5 %	617.779	28.5 %	23.2
1963	377.950	38 %	663.678	38 %	32.1
1964	405.380	48 %	710.839	48 %	41.6
1965	434.470	58.5 %	761.826	58.5 %	51.8
1966	465.540	70.5 %	815.270	70.5 %	62.7

Table 3. Electrical consumption in GWh (1.000.000 kWh according to OECD) within Europe in marketing areas, EEC and EFTA. From 1962 and onwards anticipated increase. At 7.2 % yearly rate the consumption is doubled in a decade.

It appears that the availability of power and the development of industry forms kind of a vicious circle that is responsible for the limited yearly average increase. Only when electricity is available development may take place and as soon as this starts there is immediately a need for more power. The time required for acquiring and commissioning new plant and for expanding industry limits the speed of development and there is no doubt that centralized governing such as practiced for instance in Russia may show greater achievements by planning right ahead both for electric power and industry to develop in parallel. The Russians thus claim a trebling inside each decade to be possible as against doubling when development takes place freely as in other countries. This fact is of course of greatest interest to a rapidly developing country wanting to show results and biggest possible results with smallest

possible time delay.

The next question is then to find out how much electric power is required for a certain industrial development. Here it has to be borne in mind that in ordinary communities the use of electricity for other purposes than industry rises rapidly with the state of welfare brought about by the development. OECD in their enquiry No. 12 have found that the total call for electricity rises approximately with the square of the industrial production i. e. if this is doubled four times as much electricity is consumed. This fact is also borne out by the fact that industry produces much more per head in countries with a lavish supply of electricity than in countries less fortunate in that respect.

	$ per capita and year	Electricity available
USA	17700	4111
Sweden	9200	3669
Switz erland	6900	2719
United Kingdom	6000	2005
West Germany	5400	1750

Table 4. Production per capita within the large electrical power industries in the world as compared with the amount of electricity available per head (table 1).

Table 4 shows comparative figures from the largest electrical industries in the world taken from Fortune´s list of firms and selected so as to obtain somewhat similar working conditions. Thus naturally a car maker buying most of his parts elsewhere cannot possibly be compared with a ball-bearing maker manufacturing his product right from the beginning. It is quite evident from the comparison that a higher rate of productivity is entirely dependent on power resources and it is thereby proved how extremely important the availability of ample power resources is to a country wishing to develop rapidly.

As mentioned before the diesel engine is the most usual prime mover when small quantities of power suffice and also in highly developed countries it is retained for standby power purposes in such cases where an unbroken supply has to be available such as for hospital, airports, telephone exchanges etc. but also for providing lighting in outlaying areas where the electric network cannot reach at competitive costs. Already at a few hundred kilowatt output the capital cost, however, becomes onerous with the dieseldriven alternator that does not come out cheaper per kW above a certain size and may not be able to use the cheapest fuels available.

The steam turbine although somewhat more complicated as it has to be provided with a separate boiler definitely holds its own as from 1000 kW and onwards but is supplemented by the gas turbine for cases where short time

peak load working or extremely rapid standby power is required. This prime mover is, however, not so efficient as the turbine and is therefore not put into continuous use except when gas fuels are obtained at very low cost. Neither may it be developed into larger sizes and the world record at the moment is held by the Swedish 40 000 kW gas turbine station at Västervik, Sweden. So far larger sets would not come out cheaper per kilowatt, neither show better efficiency (28 %). Development, however, takes place continuously and diesels as well as gas turbines may now be run on thicker and thicker fuels at lower and lower cost.

As load increases beyond that catered for by the smaller types of turbines it is rational to replace those with larger sets rather than to increase the number of sets. The steam prime mover is capable of such improvements as the size increases that both capital and running costs are materially reduced. In the former case a doubling may mean a reduction by 15-20 % in cost per kW installed and in the latter some 10 % reduction of fuel per kWh produced may be realized. However,there is a present limit to the latter improvement as however clever modern designers may have been, hardly more than 40 % of the calorific value of the fuel is converted into electric energy in anyone of todays plants and 45 % thermal efficiency has yet to be reached. This means a terrific waste under present circumstances and gives rise to another problem - cooling water.

Smaller plants may use cooling spray ponds for disposing of the waste heat if the plant may not be suitably placed alongside rivers or at the seaside where ample supply is available. Even then the amount of heat to be carried away may cause trouble and inconvenience as for instance with the river Thames in England cooling a large number of power stations on its way to the sea and thereby increasing considerably in temperature. The only other solution so far is the cooling tower which however provides a not inconsiderable increase in production costs and anyhow needs a certain quantity of make up water. This explains why gas turbines with their considerably smaller cooling water consumption may be preferred in desert areas for instance for gas or oil pumping plant.

In countries with a cold climate the waste heat may be used for district heating, a method very common in the whole of Scandinavia. This provides for an inexpensive combination of electricity and heat generation with consequent low costs in both instances. The method is naturally limited in its application to great cities or industries but in the latter case electricity production may also be combined with steam raising for industrial production. Counter pressure or bled turbines are used and electricity is obtained most efficiently. Particularly the cellulose industry is well served in this manner.

With larger steam turbines the technology becomes more complicated as higher pressures and higher temperatures

of the steam become economically feasible and this turns the power station into a chemical laboratory. Special steels are used to withstand the onerous conditions but if they are heat resisting they instead become extremely vulnerable to the feed water chemical treatment. Large power generation though highly economical thus requires advanced expert knowledge.

Hydraulic power is a question of harnessing streams and the storing of water which usually requires large capital but on the other hand has very small running costs. Scandinavia is particularly well developed in that respect and all kinds of plants required are there available. Of particular interest is that the rainfall usually varies in cycles in the proportion 1:2 over the years and that a rationally built plant usually provides for thermal peak load and drought standby power as it is not economical to build only for minimum flow. Sweden as an example has hydro-generating facilities for 10 % over average flow and 25 % thermal standby used however on an average only for generating a few percent of the units required over the years. ASEA is the main Scandinavian supplier of both waterwheel driven generators as well as steam turbos and gas turbines, the turbines themselves being delivered by other Swedish suppliers such as KMW, STAL-LAVAL Turbin Co. etc.

Generally speaking the capital costs for obtaining hydro-power are far more onerous than those for thermal plant but on the other hand no fuel is consumed. Countries short of, or without fuel of their own, are therefore particularly anxious to make use of their national resources and develop hydroelectric power at a preference. When due to the rapid increase in demand water power will no longer suffice nuclear power may provide a suitable replacement. So far nuclear power has not been produced at such cost as to compete neither with thermal power nor with hydro even when such plants have been given an opportunity to run continuously at full load. Average utilization is otherwise 4500-5500 hours a year or 50-65 %.

The installation of power plants requires trained staff and in the case of rapid development it may therefore be expedient to obtain assistance with this detail. British practice is to make use of consulting engineers who make the necessary preliminary investigations, specify the plant required and supervise the erection. Still more complete service is given in the case of turn-key installations where the supplier provides the plant ready erected and run up to load as well as trains the staff in the daily running schedule. With larger plants this becomes more and more difficult and it has been stated that some American utilities run their plant continuously through the years and call for the makers assistance when the equipment has to be stopped for overhaul and thereafter started again. As examples of turn-key jobs Swedish deliveries through the firm of Electroinvest to Ethiopia, Brazil and Iran may be mentioned.

With electric power once available real industrial development requires specialized plant for mining, steel making, rolling mills, cellulose factories, printing, cotton and woollen mills etc., all requiring highly developed know how. Transport problems may also be solved electrically and as is wellknown almost the entire Swedish railway system is electrified according to the now universal A. C. system. Originally the railway load was considered most important to the power system providing as it does an evening out of peaks. People do not work when they travel and vice versa and the railway thus fill the gaps when the factories rest. However, with higher development industry passes traction as a load source and the latter finally is responsible for less than 10 % of the demand. It is then important that industry and traction are fed from the same network so that the same Grid may serve both. The modern way of doing this is to feed the railway single phase at industrial frequency and to turn this into D. C. on the rolling stock by means of silicon rectifiers. Older systems run quite efficiently with A. C. motors at 1/3 of the industrial frequency by means of substation synchronous 12 pole - 4 pole frequency converters. This has also the advantage that only balanced threephase traction load at leading power factor is imposed upon the Grid system which may not be sufficiently stable to carry considerable single phase railway loads at lagging power factor.

In the case of tubes or subways as well as remaining tramway and trolley bus lines these are fed with D. C. from silicon rectifier substations along the line.

It is evident from the above that power units which in themselves may have a useful life of some thirty years will be replaced by larger sets already within 10 years time. It is therefore wise to make arrangements for the removal of the plant to new sites after this initial period rather than to let is rest inefficiently as a standby. Diesel sets provide no problem in that respect but conventional steam turbines driving separate generators require heavy foundations to deal with the torque transmitted under normal and short circuit conditions. There is, however, one special design of turbine where the generator forms an integral part of the turbine itself and the set thus lends itself to easy removal and transport. Brazil, the Argentines, India and Poland have made use of such turbines in great number for developing load until such period that the different load centres may be joined by means of a National Grid system. The design makes use of two counter rotation turbines working in one and the same shell and the same steam flow thus passing the different turbine rings of the two prime movers alternately. The two counter rotating shafts are joined together by electrical means each carrying a generator both working in synchronism on the network as one unit. This Ljungstrom type turbine only requires a very light foundation sufficient to carry its own weight and the future transport to a new site is therefore easily accomplished. Simultaneously the relative speed of the two blade sets is twice that other-

wise obtainable (6000 rpm instead of 3000 rpm with 50 cycles, 7200 instead of 3600 rpm with 60 cycles) and the efficiency consequently reaches values otherwise not obtainable for the size of set in question. The same type of turbine has been developed right up to some 300 000 kW so that in the case of extensions the staff trained on this particular design may be retained right through.

As load reaches into larger ratings another problem is added and that is two shift working i. e. some sets have to be shut down at night and started up the next morning to provide enough night load for the remaining sets to run through. The larger the set the more difficult this problem becomes with the conventional turbine where runner and shell do not heat up at the same rate and consequently complicated apparatus and skilled staff is required to maintain the narrow clearances required for efficiency reasons. Here again the Ljungstrom design with two equal turbines providing alternate blade rows in the steam, heat up at exactly the same speed and allow more or less instant starting without supervisory instruments, apparatus or special staff. Also for standby purposes this feature is invaluable as load may be taken as fast as the boiler will allow. In the latter respect modern boilers are becoming faster and faster and a study of the Swedish underground 1 000 000 MW station Stenungsund is recommended. Two Ljungstrom sets of 160 000 kW each are there commissioned and two more of about twice that size will follow.

Less fuel, less staff and decreased maintenance follows with larger sets but the capital requirements are naturally more onerous if the plant cannot be put to full use immediately. Present day power engineers have, however, found that it pays well to be in advance of requirements as the loss of interest is anyhow offset by inflation and it therefore may be good economy to look well ahead when planning. The only thing to be held against such a line of thinking is the question of modernity and efficiency. By waiting somewhat a more modern design that will resist replacement longer may be obtained and there is also the possibility of a more rational way of taking care of the fuel being developed. However, in the case of buying one or two years in advance this possible gain may hardly offset the advantage of a somewhat larger set.

Very little has been said about the transmission of energy as it is only in later stages that this becomes a major question. However, development may be achieved by means of power sources remote to the demand and considerable savings may be obtained by joining different power centres so as to provide a common standby and a levelling out of power peaks. It must then be remembered that the transport of electricity is quite a costly matter and that therefore it is usually found cheaper to transport the fuel and then particularly if it is a question of oil or gas. However, hydro electric power plants are where they are and transport by electrical means is today's only solution

of the problem of how to bring the power to the consumer. Here again it pays to plan ahead and not to select the transmission voltage too low as not to allow for future developments. The highest transmission voltage in use is so far in the 500 000 volt range as practiced in Sweden since ten years (420 000 - 380 000 volts with 500 000 volts insulation standards) but higher voltages may become necessary for larger amounts of power to be transported over longer distances. An interesting thing is there the advent of high voltage direct current transmission which incidentally solves also the cable problem and has therefore been used for marine crossings such as the English Channel, Cook Strait, New Zealand and Sardinia to the mainland in Italy. Here the alternating current would provide great difficulties with the large capacity current of the cable and also uses a 40 % higher peak voltage than the corresponding D. C. transmission.

In the case of the English Channel the cable runs East-West with the sun and thus finds the daily peaks distributed at different periods in the two countries joined by means of the D. C. link. Theoretically such a cable right across the American Continent would take care of all the peaks in the seven hour time difference traversed without the necessity of any new generating equipment being provided. In that case an A. C. link is also possible but would involve synchronous running of the entire system with the risk of considerable overloading of the link hereas the D. C. link only transmits the power it is set to deal with.

As development goes on electricity plays a more and more important part in the production of a higher standard of living starting in a modest manner with lighting and fans, with or without air-conditioning right up to the present day completely electrified town life where manual power is substituted by mankinds servile slave electricity.

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